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Lubrication

A Technical Publication Devoted to the Selection and Use of Lubricants

THIS ISSUE

Diesel Engine Lubrication
Bearing and Air Compressor Requirements

Common Faults in Lubrication

PUBLISHED MONTHLY BY
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Diesel Engine Lubrication

Bearing and Air Compressor Requirements

WRIST pins, crank pins, main bearings and crosshead guides of Diesel engines require careful lubrication. With the possible exception of the wrist pins which are contained in an enclosed position and may be subjected to considerable unradiated heat, the above parts will, in general, involve no difficult lubricating problems. Pressures are usually high, clearances low and operating speeds frequently high; yet the circulating force feed oiling system, the mechanical lubricator, or the principles of splash lubrication (in the enclosed crankcase engine) are all readily adaptable.

On large engines the first is preferred by many authorities. In effect it is probably the most dependable system in that it furnishes a continuous stream of oil to all the bearing parts in question, assures an adequate oil wedge, assists materially in cooling and is capable of being put in series with a filtration or purification system which will insure the delivery of practically pure oil, thus eliminating the possibility of clogged oil ways. Furthermore, the oil feed to each part, in certain cases, can be independently controlled.

One oil is generally used for all bearings of a Diesel engine and should be selected to suit those bearings subjected to severest operating conditions. With the mechanical lubricator it is possible to make it serve both cylinder and bearing lubrication, by keeping the requisite lubricants in separate compartments, although where but one grade of oil is required this would not be necessary. With more than one oil there is, however, always a possibility of these being mixed up and for this reason many authorities insist that separate lubricators be used under such conditions.

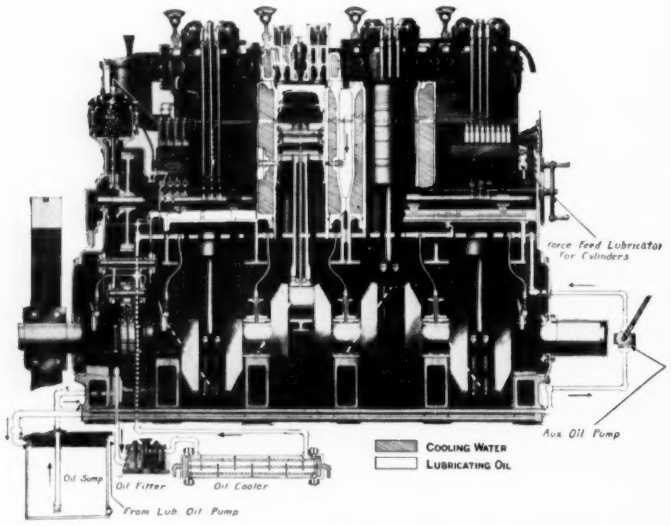
A variation exists in the pressures used on lubricating systems. While with some engines the pressure will not exceed five pounds per square inch, in others it is carried as high as twenty pounds per square inch. This pressure will be influenced by bearing clearances, and a noticeable drop in pressure may occur with a new engine as the wearing in of the bearings progresses.

Mechanical Force Feed Systems

Force feed lubrication is perhaps the most popular means of delivering oil to the cylinders of a Diesel engine. Force feed lubrication as used for cylinders and air compressors can be regarded as high pressure lubrication, where pressure as high as 1,000 pounds per square inch is employed, as compared with the relatively low pressure systems used for the miscellaneous bearings of certain types of engines.

With force feed lubrication each lubricator consists of several individual adjustable pump plungers receiving their oil supply from a reservoir in the body. They feed accurately measured quantities of oil to suit the parts being lubricated. Sometimes provision is made for lubricating the piston pin by the same means, although the piston pin may be lubricated by the bearing circulation system. Several leads are usually employed to conduct the oil to the cylinder walls, the number depending on the size of the cylinders.

Where force feed lubrication is used on main and other bearings, they are flooded with a continuous and adequate supply of oil which assures the formation and maintenance of a complete lubricating film at all times. A mechanical force feed lubricator, being practically always driven by the machine which it serves, only functions when the latter is in operation and at a proportional speed. The pumping capacity and rate of oil feed is therefore variable. By suitable adjustment of the lubricator it can be very accurately regulated to meet whatever lubricating requirements the bearings may involve. On some of the smaller Diesel engines the mechanical lubrication system is employed for the bearings as well as for the cylinders. Oil so fed to the bearings is usually recovered from the engine crankcase, filtered, and cooled, and returned to the mechanical lubricator for re-use.



Courtesy of Chicago Pneumatic Tool Company

Fig. 1—Sectional view of Type RHA Diesel engine as manufactured by the Chicago Pneumatic Tool Company, showing cooling and lubrication systems. Note path of used and of cleaned oil through sump tank, oil filter and oil cooler.

Pressure Circulation Systems

The continuous circulation of oil through bearings affords a very practical and economical way of automatically lubricating such parts with a minimum of labor and attention. As a rule, a considerably greater volume of oil will be involved in a circulating system than in a mechanical force feed lubricator.

A typical circulating system will involve a suitable oil reservoir in the base of the machine, a pump for transmission of oil either to an overhead auxiliary tank, or directly to the bearings to be served, and the necessary distributing pipes to each of the latter. Each line should be fitted with a sight feed device and adequate means for individual adjustment of oil flow. Means will also be necessary for drainage or transmission of used oil back to the base reservoir or sump tank.

Such a system is advantageous in that it provides for sufficient settling of the oil to insure precipitation of the greater part of any foreign matter that may have been picked up by the oil in passage through the bearings. Furthermore, the latter are practically flood lubricated, which not only means that they will normally be washed free from accumulations of foreign matter, but also cooled to a certain extent.

It is also perfectly practicable to provide for adequate pressure either by gravity or pumping, to maintain a sufficient pressure on the oil films which partly serve to resist such operating or reaction pressures as may be involved on certain of the bearings. With some installations the pressure gauges of the lubricating system are equipped with both high and low pressure alarms to call the engineer's attention to pressure changes beyond permissible limits.

This is the usual system employed for lubricating the various bearings of Diesel engines. A circulating oil pump driven off the engine delivers the oil, under pressure to the main bearings and through ducts to the crank pins, piston pins and other parts requiring to be lubricated. After passing through the bearings the oil drops back into the crankcase from which it is pumped to a separator or other purifying device from which the oil is again recirculated through the system. In order to keep the oil at or near a constant, moderate temperature, water cooling coils are sometimes employed to dissipate the heat acquired during circulation through the system.

Splash Oiling

This system is used on comparatively small cylinder, high speed engines where the circulating oil for the bearings also furnishes the lubrication for the cylinders. In this type of system the cylinder lubrication depends primarily upon the oil throw or splash from the crankcase. During each stroke an oil film is formed on the lower part of the piston and cylinder wall which is replenished on the successive upward stroke by the piston rings as they pass over. The oil drains by gravity to a reservoir within the crankcase.

Efficient lubrication results in these engines because of the liberal amount of oil thrown

from the moving parts on its escape from the bearings. For such service a lower viscosity, minimum carbon oil is recommended with the characteristics of a bearing oil, in the neighborhood of 300 to 500 seconds Saybolt at 100 degrees Fahr.

Ring and Chain Oilers

The lubrication of main bearings is sometimes accomplished by the use of ring or chain oilers. A continual delivery of oil is assured to the wearing surfaces by means of a ring or chain suspended from the shaft, and free to rotate therewith, the lower part dipping in a bath of oil which is carried in a suitable reservoir in the lower part of the bearing shell.

In order to insure effective lubrication by such mediums the reservoir must be of adequate capacity to give the oil ample opportunity to rest, thereby making possible not only the settling out of sediment and other foreign matter, but also cooling to the requisite degree. As a rule, the only way in which the oil in such a system is kept at the proper temperature is by radiation of heat from the interior surfaces of the reservoir or lower part of the bearing.

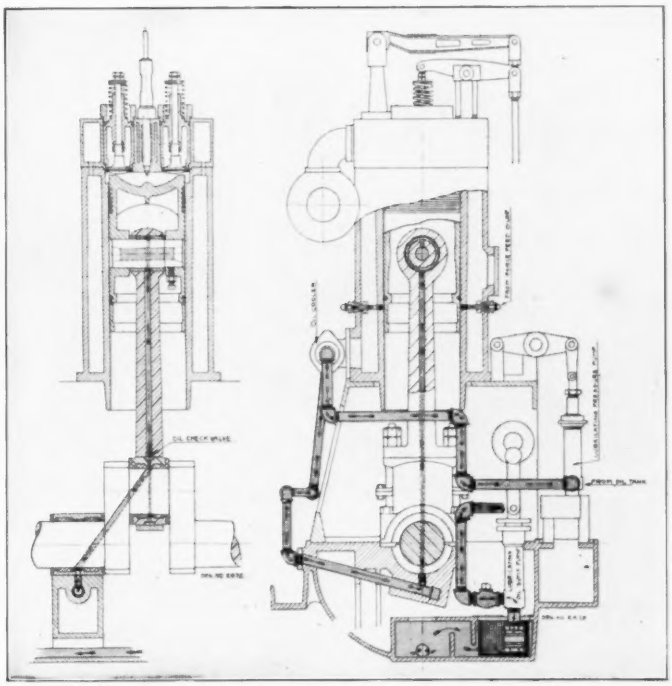
Oil which is carried to the top of a ring or chain oiled bearing must be returned to the reservoir as rapidly as it is delivered by the ring in order to avoid accumulation of oil in the upper part of the housing to be forced, ultimately, out from the ends of the bearings. The same condition may arise if the oil is carried too high in the well, or if the ring rotates at too high a speed. This will cause a splashing and churning of the oil.

On some engines lubrication of the main bearings, particularly those on the outboard side, is accomplished by the use of oil rings and by a subsequent distribution of this oil to the journals upon which the rings ride. The oil is collected from around the main bearings or else from a separate gravity feed supply in the centrifugal banjo coils or rings, attached to the crank webs. By means of centrifugal force a positive flow of oil is made to the crank journals through drilled holes.

A system of gravity circulation of oil is found on small sized engines. Although the oil circulation is continuous and automatic, the oil is not supplied under pump pressure in this type of system.

Oil Throw

In lubricating systems where oil throw is used, the oil escapes from the crank bearing and is subsequently thrown to the cylinder walls of single-acting engines in sufficient quantities to assure liberal lubrication. The employment of this non-forced lubrication necessitates certain special features in connection with the crank-shaft. Rings are turned on the latter, at each end of the journal, to throw the squeezed out oil into suitable catcher grooves in the bearing brasses, whereby it is returned to the oil well instead of being thrown off by the crank webs.



Courtesy of Atlas Imperial Diesel Engine Company

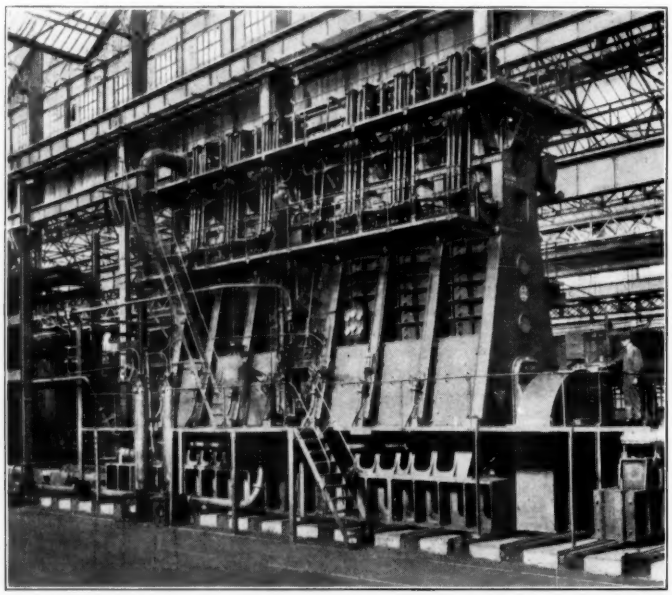
Fig. 2—The left hand illustration shows the method of lubricating by force feed the crank and piston pin of a four-cycle Atlas Imperial Diesel engine. The right hand picture illustrates the pressure circulating system of lubrication. Oil that collects in the base is picked up by a pump and, after passing through a filter, is returned to an oil manifold maintained at a constant pressure. From this manifold, oil pipes conduct the lubricant to the several bearings.

Amount of Lubrication

The quantity of oil circulated through a bearing lubricating system varies widely in different engines, being dependent on the size and speed of the units as well as the design of lubricating system installation. The chief requirement is that the amount circulated shall be greatly in excess of what is actually required for lubrication, so that the large amount of oil flowing through the bearings may serve as a cooling medium in addition to maintaining a film between the bearing surfaces.

In the matter of overheated bearings there

is little criteria—no two people will agree upon the degrees of warm, hot and too hot. An engine operator can only trust to his own experience. A landsman and a sea-going engineer will both have the most diverse ideas what may and may not be run safely.



Courtesy of Burmeister & Wain

Fig. 3—A six cylinder, single acting, crosshead engine of the long stroke type under test in the shops of Burmeister & Wain. Such Diesel engines of large powers are force feed and pressure lubricated throughout, and the pistons are cooled by means of oil entering and leaving by telescopic pipes fitted to the crossheads.

Oil Wedge Principle

Where shafts or journals, such as the main and other bearings are involved, effective lubrication can be most dependably attained by providing for passage of oil from the low pressure to the high pressure area. As a general rule this will mean from the upper to the lower part of the bearing.

For this reason oil holes are usually located in the top part or cap of the average bearing, when lubrication is to be maintained from an external source. In addition, by suitable grooving of the top part or low pressure area of such bearings, where practicable, delivery of adequate oil to the point of entry of the high pressure area can be more nearly obtained.

When a bearing which is at rest, starts to revolve, the lubricating oil adhering to the journal is drawn in the form of a wedge into the pressure area. If the velocity of the bearing is very low, and especially if the oil be viscous, it is very possible that no oil film will be formed. It is claimed, however, that with a velocity as low as ten feet per minute oil is drawn into the bearing of the journal and forms a wedge. This wedge of oil forces the shaft over and raises it in the horizontal direction, at the same time completely separating it from the bearing. As the velocity increases, the thickness of the oil film becomes more uniform and the center of the shaft approaches more closely to the center of the bearing. If the load be now increased, as the speed is kept constant, the journal tends to approach a point on the bearing about 40 degrees from the vertical. If a further increase in load be applied the oil film will be ruptured with resultant friction, hot bearings, wear and possible breakdown of the unit.

Oxidizing Influences

Oxidation occurs on all types of engines and is due to the gradual absorption of oxygen by the oil. It becomes evident by the presence of a brownish sludge, if the oil is left undisturbed for some time. The lubricating oil in a pressure circulation system enters the bearings and assists in the formation of a wedge shaped oil film. Upon its escape from the ends of the bearings it is thrown violently about in the crankcase and broken up into fine spray due to the action of the revolving crankshaft. There is thus a very large surface of the oil in an atomized state exposed to the attack of oxygen.

This fine oil spray coming in contact with the hot air in the crankcase is subjected to an oxidizing effect, especially in the presence of water and other impurities. This oxidation, accelerated by the constant churning effect, promotes emulsion and has a very detrimental effect on the lubricating oil. Careful selection of the crudes from which the oil is manufactured and equal care and skill in its refining will produce a high grade lubricating oil suitable for this service.

Other Influencing Factors

There are other additional burdens placed upon the oil in a Diesel lubrication system. Impurities which may contaminate the lubricant may be caused by water leakage from the cooling system, or deposits from fuel oil, or dust contained in intake air. These may reach the lubricating oil in the crankcase in the form of cylinder drip.

In engines where lubricating oil is used for cooling the pistons the discharge from the piston head is sometimes led direct to the crank pit, allowing the piston cooling oil to mix with the bearing oil. This oil, in its circulation through the pistons has naturally come in contact with the very hot inner wall of the piston head. The oil must be able to resist to

the greatest extent any tendency toward breakdown when exposed to this high temperature. The formation of carbon deposits on the inside of the pistons will retard the transmission of heat from the piston to the circulating oil whereby the setting up of excessive heat stresses may result in cracked pistons.

Results of Oil Breakdown

It can be readily appreciated that the severe service conditions prevailing in a Diesel engine lubricating system will result in breakdown of inferior or unsuitable products. This is usually manifested in the precipitation of gummy deposits, although these are not always easily detected and the oil may still appear to be in fairly good physical condition. These gummy deposits are most dangerous when they lodge within the oil pipes leading to the bearings, or the oil ducts within the crankshaft or the connecting rod. The accumulation of such deposits may not be observed until sudden restriction or stoppage of oil to some bearing or group of bearings may cease entirely, with resultant burned out bearings and possible serious consequences.

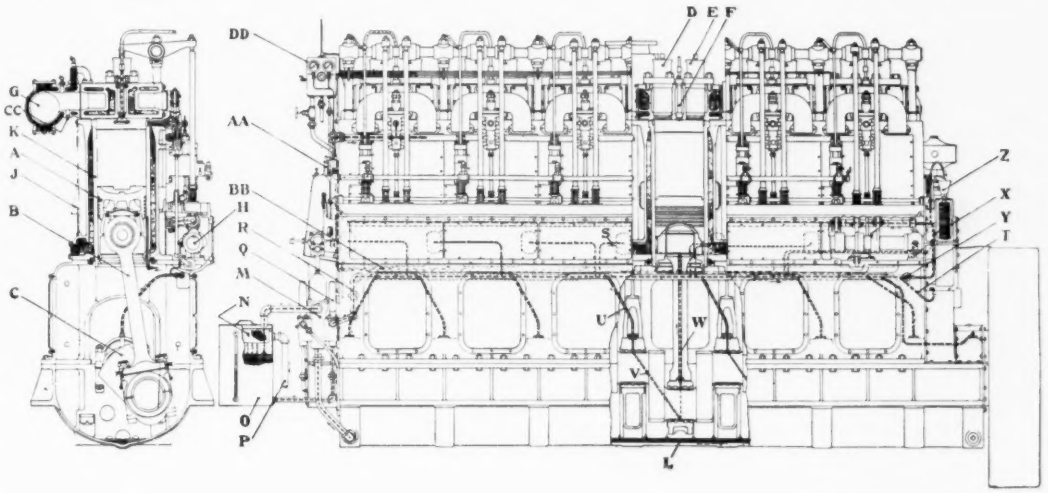
Bearing Wear

Bearings may be classed generally under two divisions: journal bearings and thrust bearings. Journal bearings are cylindrical and the load is carried at right angles to the axis of the bearing. When the load is carried or applied in a line parallel to the axis, we have what is called a "thrust" bearing. In addition, a further class might be added consisting of those bearings which permit moving parts to slide over them, such as the crosshead guides. These are known as "sliding-contact" bearings.

The difficulty presented in supplying proper lubrication to a cylindrical bearing arises from the fact that the lubricant will not flow at right angles to the axis of the journal, nor parallel to the line of surface motion, but has a tendency to flow at various angles from such lines, and always toward the ends.

The evil and undesirable consequences of excessive bearing wear may be as serious as those of excessive cylinder wear or even more so. It is impossible for metal surfaces under pressure, such as journals and bearings to rub one on another even for short periods without generating heat, which will quickly become excessive and eventually destroy the material. Such surfaces must be positively separated by a film of lubricating oil.

While cylinder wear, in extreme cases, leads to loss in compression and consequent loss in power, excessive main bearing wear in addition to loss in power may also lead to fracture of the crankshaft. Bearing troubles are not always apparent or audible. In a two-cycle, single acting engine, for instance, where the load on a bearing is always in one direction, that is, downward, quite a bit of wear may exist without any audible signs, while in the four-cycle engine comparatively smaller amounts of wear may be indicated by pounding at the end of the exhaust stroke.

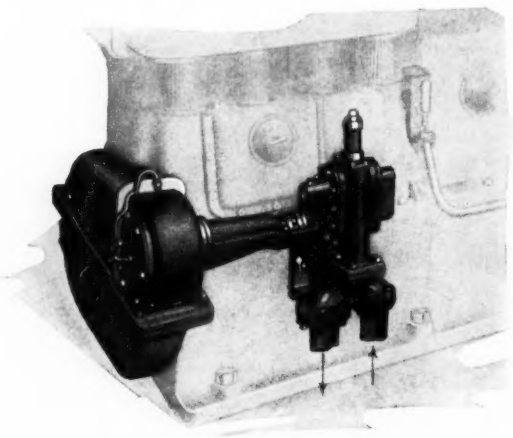


Courtesy of Electric Boat Company

Fig. 4—Details of lubricating oil system, as installed on a modern four-cycle Nelseco Diesel engine. A—Piston. B—Connecting Rod. C—Crankshaft. D—Inlet Valve. E—Exhaust Valve. F—Injection Nozzle. G—Exhaust Header. H—Camshaft. J—Intake Silencer. K—Cylinder Liner. L—Oil Sump. M—Oil Return Pump. N—Oil Strainer. O—Oil Service Tank. P—Oil Overflow Pipe to Sump. Q—Oil Pressure Pump. R—Distributing Oil Header. S—Oil to Camshaft Bearings. T—Oil to Camshaft Drive Gear Pin. U—Oil to Main Bearings. V—Crankshaft Drilled for Oil Passage. W—Oil to Wrist Pin Bearing. X—Oil to Cam Roller Rocker Shaft. Y—Adjustable by-pass Relief Valve. Z—Overflow Oil to Gears. AA—Mechanical Force Feed Lubricator. BB—Oil Lines to Cylinder Walls. CC—Pyrometer Connection. DD—Fuel Oil Reservoir Providing Constant Pressure Head.

Effect of Oil Body

The resistance of an oil film to squeezing action is dependent on the body or viscosity of the lubricating oil, the size of the engine bearings, the speed, the unit pressure and the temperature of the oil.



Courtesy of Aktiebolaget Atlas Diesel

Fig. 5—Showing a gear wheel pump for lubrication and cooling of Atlas Polar Diesel engines. Oil is delivered by the gear wheel pump in this forced lubrication system to the main bearings, top and bottom end bearings, while the cylinders are lubricated by means of a special forced feed lubricator.

Under conditions of starting, or in the case of slow movement as with piston pin oscillation or crosshead bearings, the formation of an oil wedge and maintenance of an oil film are effected, and there is a tendency of the oil film to be squeezed out of the pressure area. Viscous or heavy oils produce a thick lubricating film and it is for this reason more difficult to squeeze the heavy oils from between bearing surfaces. Such oils are used where the bearing pressures are high, the clearances large or the temperature of operation high. Of course, if too heavy an oil be selected for a certain service the fluid friction and the consequent bearing temperature will become excessive, and the separation from inevitable impurities within an oiling system is made difficult.

It is necessary to use a thin oil where high speed bearings are employed because it gives the minimum of friction, and because the friction generated by the high rubbing speed of the journal would be abnormally increased by the use of a heavy oil. In high speed bearings the bearing pressure is generally light, which permits a thin oil. However, if too light an oil is used, the lubricating film is not sufficiently viscous to keep the metal surfaces apart. This will readily cause rapid wear and result in burned out bearings. As such an oil is readily atomized on escaping from the bearings, the spray thus formed in intimate contact with air promotes oxidation. Excessive lubricating oil consumption may also result from the use of too light an oil according to the engine design, operating conditions and opportunities for oil leakage.

Frictional Resistance

Probably the principal reason why the lubrication efficiency of oil is not given more general attention is because a great proportion of the losses incurred through faulty lubrication are hidden. As long as an oil is not giving any unusual or flagrant trouble it is often assumed that it is efficient, while as a matter of fact, the use of an improper lubricant may be causing a heavy power load factor.

A condition met with in lubrication that does not seem to be fully apparent to the average user of oils, is that frequently there are chemical or physical imperfections in the metals of the bearings or journals, or some mechanical defects in the fitting of these parts that are not discernible by the naked eye. Yet tests have clearly indicated that excess friction and correspondingly high temperatures can be, and often are, caused by variations in the smoothness of the bearing or journal surfaces that cannot be easily detected.

All surfaces are more or less rough; even surfaces which are well machined and polished show under the microscope small projections and depressions. It is the interlocking of these minute projections which causes solid friction when two surfaces are pressed together and move relative to one another without lubrication.

The object of all lubrication is that the lubricant should attach itself to the rubbing surfaces, and form a film between them, which under the conditions of speed, pressure and temperature prevailing will not be squeezed out, but will keep the frictional surfaces apart. In perfectly lubricated bearings the rubbing surfaces never actually touch one another and the friction is entirely dependent on the lubrication. The frictional resistance with fluid friction is dependent upon the speed and area of the rubbing surfaces and the viscosity of the lubricant at the working temperature of the oil film, but is independent of the pressure between surfaces, the condition of the rubbing surfaces, and the materials of which they are composed.

When an engine stands idle for some time the oil films on the various working parts are more or less completely dissipated. The sustained pressure, due to the weight of the parts has caused the oil films to be squeezed out with the development of a certain amount of metallic contact. This results in a considerable starting effort of an engine and the static coefficient of friction approaches that of solid

friction. The starting effort will, of course, depend on the conditions and nature of the surfaces in contact and the pressure between them.

Just as the surfaces begin to move the kinetic coefficient of friction comes into play, but as the speed increases and oil film is formed, the kinetic and solid friction decrease until perfect film formation is attained. The high values of the static coefficient easily explain the great effort often required to start an engine from rest; therefore, the introduction of ball or roller bearings, where there is practically no difference between the static and kinetic coefficients would be advantageous.

Miscellaneous Lubricated Parts

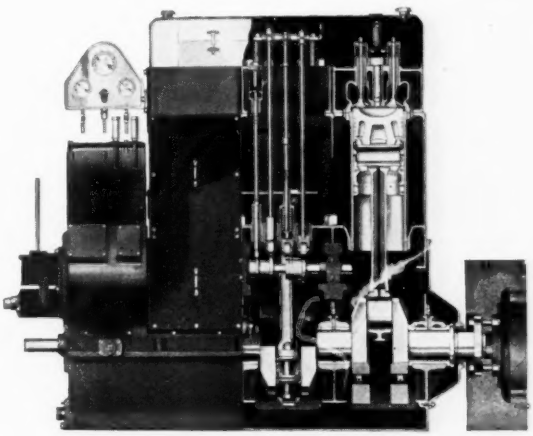
Inlet and exhaust valves of Diesel engines require oiling but this must be done sparingly. If too much oil is applied to the exhaust valve spindle it will only burn and carbonize, and may quite easily cause a seizure of the valve stem. A usual practice to keep exhaust valve stems free is the periodic application of a small amount of kerosine while the engine is running. Valve rocker arms are usually lubricated by hand, although in some designs from the circulating system.

Cam-shafts are generally lubricated by feeding off the main circulating system. Owing to the low peripheral speeds and the intermittent loads no difficulty should be encountered. The cam-shaft is usually gear or chain-driven, and as the lubricant for these drives is necessarily the same as that used for the crank chamber, note of the drive should be made when selecting a suitable crankcase lubricant.

AIR COMPRESSOR LUBRICATION

In the air injection type of Diesel engine, the air compressor can probably be regarded as the heart of the system by virtue of the important part it plays to bring about combustion. To serve this purpose, however, it is absolutely necessary that the compressor be properly lubricated. It must be served with just the right amount of the most suitable grade of oil, and its lubrication is regarded as the secret of successful compressor operation.

The air compressor as usually installed in higher powered Diesel engines will generally have either three or four stages, and will be equipped with suitable inter-coolers. The exact quantity of air required for injection is difficult to determine; moreover, since it varies with different fuels, and the compressor must also provide air for starting purposes, ample margin is usually allowed for in the design. The compression of air to pressures in the neighborhood of 1,000 pounds will, of course, develop a considerable amount of heat; it is the function of the inter-coolers to reduce this heat and thereby keep cylinder temperatures down to minimize the extent of oil vaporization. This is, of course, in the interests of safety, for otherwise accumulations of dust and carbonaceous matter in the inter-coolers, etc., might



Courtesy of Superior Engine Company

Fig. 6—Transverse section of a direct reversing Superior Engine Company Diesel engine where the pressure lubricating system supplies all the bearings with oil under approximately fifteen pounds pressure, which insures ample lubrication. All working parts, including lubricating oil pumps, are completely enclosed preventing loss of oil. Lubricating oil is re-cycled through a filter and cooler insuring minimum consumption.

easily so restrict the air passages as to increase the velocity and consequently the frictional temperature of the air to a dangerous extent.

Methods of Lubrication

To best effect air compressor cylinder lubrication, each cylinder should be equipped for force feed or pressure lubrication, whereby uniform and measured quantities of oil can be fed regularly. Only a drop or two a minute to the first one or two stages will be necessary.

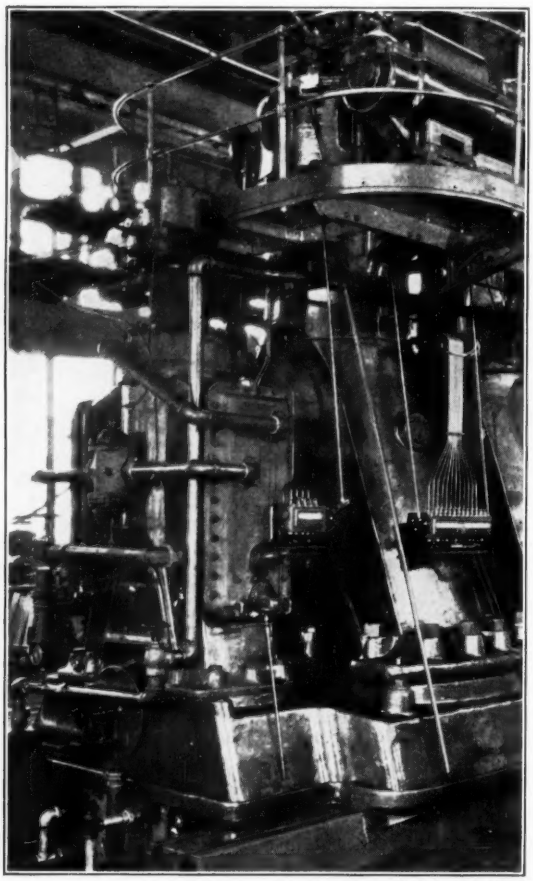
The third or last stage will usually be abundantly served with oil carried up from the preceding. On the other hand, no hard and fast rule can be laid down in this regard, and the safest course to follow in determining upon the quantity of oil to use is to remove the valves at periodic intervals and examine the cylinder walls. A properly lubricated wall should be coated with a film of oil which will just barely dampen or stain a cigarette paper.

Source and Effect of Moisture

The presence of an excessive amount of moisture in the form of free water requires careful consideration in the efficient operation and lubrication of high pressure air compressors. While water separators are provided, in conjunction with the air inter-coolers, to remove the water from the air, this removal is rarely complete. Compressor troubles caused

by the presence of water are most apparent in the final stages.

The compression of the air and its subsequent cooling in the intercoolers results in the condensation of water vapor which, to a greater or lesser extent, is always present in the atmosphere. Although the separators referred to are depended upon to remove the greater part of the water, yet an appreciable amount is carried along with the high velocity air leaving an intercooler and on into the next stage cylinder. The rush of this high velocity compressed air, in a very wet condition, into the comparatively small diameter cylinders is very detrimental to the lubricating oil film if this is not sufficiently adhesive.



Courtesy of Fulton Iron Works

Fig. 7—End view of a four-cycle, 23 inch by 26 inch Fulton Diesel engine, depicting the injection air compressor and one cylinder. The force feed lubricators and their respective piping are readily discernible.

This free water which has been carried along with the air into the cylinder for final compression often has a washing effect on the lubricating oil film. Where this may prevail the maintenance of an efficient oil film on the cylinder wall is impaired during the compression stroke and it is difficult to develop effective seals between piston rings and cylinder walls.

The lack of a proper lubricating film results in blow-by of air and excessive wear, especially toward the end of the compression stroke when the pressure behind the piston rings is at a maximum. In addition, the presence of moisture and air may cause the rusting of valves, piston rings and cylinder walls. The development of moisture will frequently be revealed upon inspecting high-pressure air compressor cylinders after the unit has been shut down. The rust formation which will inevitably follow causes pitting of valves and forms a grinding substance between piston rings and cylinder walls which results in further wear.

To meet the above requirements, it is customary practice to compound many oils for Diesel engine air compressor service with a small percentage of high grade fatty oil, which will render the resultant product especially adherent to wet metallic surfaces. A properly prepared air compressor oil is capable of developing and maintaining a tenacious water resisting lubricating film while in service and also preventing rusting or corrosion of the cylinder walls as well as the piston and rings during idle periods.

Overheating and Flash Point

The subject of the heat due to compression causes some confusion in the minds of operators as to the interpretation of the flash points of lubricating oils for air compressors.

Flash point readings are of value only as an indication of the relative initial volatility of different oils, and are not definite temperatures at which they "boil" or go completely into vapor corresponding to the boiling point of water.

Oils of the proper consistency which leave unusually low carbon residues are much to be preferred to oils of high flash point. Certain engineers, however, in their eagerness to secure oils of high flash point will frequently overlook this matter of subsequent carbon deposits. This is, of course, erroneous.

It is sometimes assumed that a high flash point is a desirable quality of a lubricating oil for air compressor service. The thought is that a high flash point will prevent the loss of oil from the cylinder walls through evaporation thereby lessening the danger of explosions. However, laboratory tests have been made with high quality, light body lubricating oils having a flash point between 310 and 325 degrees Fahr. These tests showed that negligible quantities were distilled off up to a temperature of about 615 degrees Fahr., at atmospheric pressure.

It appears that the rapidity of evaporation of an oil, as well as its tendency to carry oil vapors from the cylinder wall film over into the dis-

charge pipes and intercoolers is not governed by the flash point alone. Moreover, it appears that even with such an oil of too high a viscosity for compressor lubrication, a temperature of about 600 degrees Fahr., would not generate sufficient vapors to form an explosive mixture. The discharge temperatures in air compressors range in the neighborhood of 325 degrees to 375 degrees Fahr., and, since the cylinder walls are always jacketed it is natural that the oil film on the wall has a temperature lower than the discharge air.

Over-Lubrication

Even the best oil is at times carried over with the discharge air in liquid form when compressor cylinders are over-lubricated. This discharge air sweeping over the wetted surfaces carries small globules of oil along with it. The result will be an accumulation of oil and carbon deposits on the discharge valves which are directly in the path of the hot discharged air. Not being separately cooled like the cylinder walls, these valves have the highest temperature of all compressor parts. This is further proof that high flash point oil is unnecessary as these high valve temperatures cannot condense oil vapors from the colder cylinder walls. It must, therefore, be assumed that carbon which is found on the discharge valves leave the compressor along with the air.

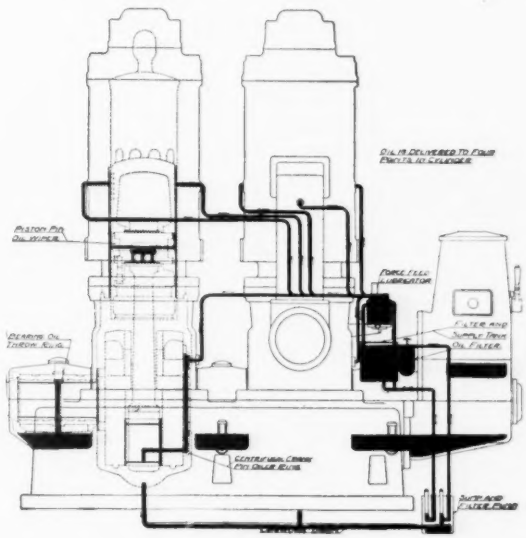
Oils too heavy in body for compressor use will tend to deposit more carbon than an oil of the right body. Furthermore, heavy body oils distribute very slowly and require excess feed to assure a complete lubricating film being maintained. Over-lubrication, especially where a high carbon residue oil is used, promotes carbon and may be the cause of air compressor explosions. Consequently not only must an oil be most carefully selected, but also, whatever its characteristics, the utmost care should be taken to prevent the use of more oil than is necessary.

In this respect, it is very difficult for some operators to realize that but one or two drops of oil per minute is all that is necessary. This is effectively counteracted in many Diesel air compressors by so designing that the intermediate stage is at the bottom. As a result of such construction there is always a pressure opposing the tendency of the oil to work up into the air space from the lowest cylinder wall where it is thrown by the crankpin.

Dirt and Carbon Deposits

While dirty air is perhaps one of the most general causes of accumulations of foreign matter, yet, as has been pointed out, an excessive amount of lubricant will tend to develop carbonaceous matter which will materially increase the accumulation of deposits.

In addition, an excess of oil fed to the compressor cylinders may bring about leaky valves due to a certain amount of the oil becoming carbonized on the latter. All this, of course, leads to a decrease in operating efficiency for this carbonaceous matter being


OIL IS DELIVERED TO FOUR POINTS IN CYLINDER
PISTON PIN OIL GROOVE
FORCE FEED LUBRICATOR
FILTER AND SUPPLY TANK OIL FILTER
DRAIN OIL TUBES
CENTRIFUGAL CRANK PIN OILER RING
SUPPLY AND FILTER PUMP

Courtesy of Muncie Oil Engine Company

Fig. 8—Schematic view of a two-cycle Muncie engine clearly illustrating the methods employed for lubricating all moving parts. A force feed lubricator is mounted upon the engine for the lubrication of the cylinder, piston pin bushing, and crank pin bushing. The main bearings are ring oiled from a bearing oil reservoir just beneath each bearing, while the governor and injection pump mechanisms are flood lubricated from the oil which circulates in these compartments.

relatively sticky in the early stages of its formation, will also tend to adhere to the piston rings, thereby causing them to become inoperative; furthermore, it will tend to destroy the lubricating film and result in scored cylinders.

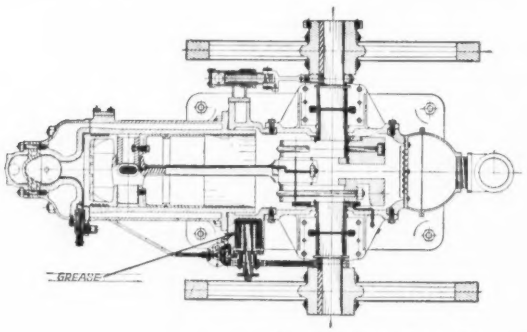
Unfortunately there is no oil which will not deposit some carbon. On the other hand, there is a surprising difference in the nature and quality of this carbon which will be developed by different oils.

Air Compressor Explosions

The different stages of air compressors are so arranged as to compress the air at the same ratio correspondingly, so as not to overheat the valves in any one of the stages, and thereby damage the valves and springs; also, to obviate the danger of lubricating oil vapors becoming ignited with consequent explosion.

Cases of air compressor explosions which have been investigated carefully have suggested that the cause was excessive carbon deposits on discharge valves, piping and intercoolers which had restricted the area of the passages. Such accumulation may interfere with valve

seating. Leaking discharge valves may result in a rapid increase of the compressed air temperature to a degree far above the highest flash point of any lubricating oil. The abnormally high temperatures of the air causes the carbon deposits to become incandescent which,



Courtesy of Weber Engine Company

Fig. 9—In the Weber oil engines the lubricating oil is pumped by an automatic force feed lubricator to the piston, piston pin, crank pin and eccentric, while the main bearings are flood oiled by means of a ring passing over the journals and dipping into a reservoir or cellar located directly beneath the bearings. After circulating through the main bearings all the lubricating oil drains back into the reservoir to be cooled and used over again.

in turn, will result in a rapid formation of oil vapors from these deposits as well as from any excess lubricating oil present in liquid form. An explosive mixture is thus formed with the hot compressed air, which is eventually ignited by the incandescent deposits.

The real cause of many explosions has never been satisfactorily explained. Some of them have occurred in piping remote from the compressor, and hence at places not subjected to the highest temperatures. Oil made from inferior stocks is therefore, inadvisable for compressor lubrication, even though it may be cheaper; the probability of very high carbon residues becoming great should preclude their use.

Cleanliness of Compressor

It is very desirable to clean out the air compressor system at intervals and wash out the carbon deposits before they grow to large proportions. Kerosine or any similar light oil must under no circumstances be used for this purpose, because of the danger of explosive mixtures due to their high volatility, and the comparatively large quantity used.

Some operators look with favor on the use of soap suds for cleaning, the solution of soap and water being fed into the air intake or through the lubricator about ten times as fast as the usual oil supply. The quantity used must be judged by the amount of carbon found on the valves when they are inspected. After such an application all receivers must be blown down to remove all the soapy water, and oil used again for a time before shutting down, in order to prevent rusting.

Common Faults in Lubrication

THERE are certain details in the practice of industrial or power plant lubrication which may frequently be the cause of decidedly unsatisfactory service, for they will vitally affect the degree to which the lubricants involved will function as intended.

These will comprise:

Improper Storage
Careless Handling
Faulty Application, and
Lack of Appreciation of Lubricating Requirements.

There was a time when any consideration as to their relation to production and machine efficiency was entirely overlooked. Perhaps this was excusable in view of the nature of the lubricants obtainable in the earlier days of the lubricating engineering profession, and especially on account of the prevailing operating standards. Nobody realized in those days the extent of service which might be obtained from a turbine bearing, nor did we appreciate the fact that measured lubrication might improve air compressor cylinder efficiency so markedly as has been indicated.

The scope of the problems involved was simply not appreciated, nor was there realization of the relationship of effective and cleanly lubrication to machine production, efficiency of operation, maintenance expense, and the ultimate cost of the products involved, whether it was steam, cotton goods, newsprint or steel plates.

In justice to the executives and machine operators of those days, however, it is fair to state that means of lubrication were crude, storage facilities were frequently inadequate, and labor untrained in the matter of the cost of wasted oils, or the potential hazards should they be allowed to drip from and accumulate around machinery.

Today, however, there has come a complete renaissance by reason of the studies of the machinery builder, the lubricating engineer and the designer of lubricating equipment.

The petroleum industry, in turn, has set as

one of its primary ideals the refinement of lubricants to the highest degree of purity. Through the hearty cooperation of mechanical and chemical engineering specialists, coupled with research physicists, this goal has been widely attained, to the end that lubricants as marketed by the reputable leaders in the petroleum industry can be absolutely depended upon today in regard to their purity.

STORAGE METHODS

Extension of any study of lubrication to the several fundamental features, which in the end will determine the degree of success which can be attained from the use of any particular lubricant, requires primary consideration of storage methods and facilities, and the elimination of improper practices.

In this connection one must remember that initial protection is essential. As a result, wherever a considerable volume of lubricant is used a central oil storage house should be provided, or at least a special room should be reserved in some part of the plant from which lubricating oils and greases can be issued to the various departments on requisition, and in suitable though not excessive quantities. In turn, all new supplies of such oils should be delivered here for storage until required, in order to insure the utmost protection against contamination.

Choice of Storage Location

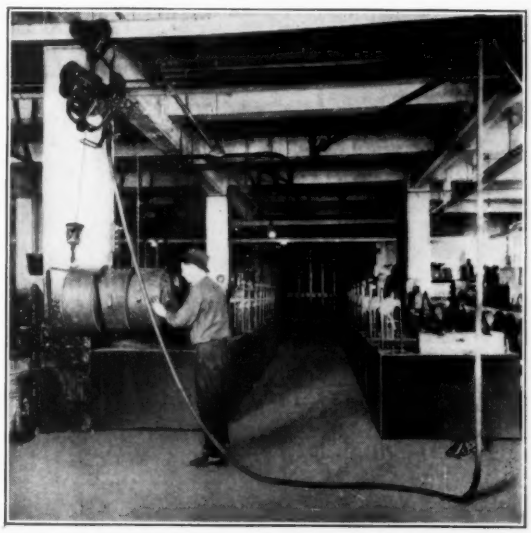
Justification for the construction of an independent oil house will, of course, depend to a great extent upon the amount of plant equipment to be lubricated. Naturally there will be considerable expense attached to such an installation.

For this reason many plants which are adjacent to oil supply stations frequently set aside a corner of the engine room or store-house for the storage of lubricants and keep them in shipping containers until empty, when they are returned to the oil dealer.

There is an objection to oil room storage, however, in that there will be considerable possibility of contamination of the lubricants, especially where plant cleaning is done in a careless manner, resulting in the possibility of dirt being swept or hosed into drip pans and measures. There will also be considerable chance for leakage and wasting of oils in such a room, unless an unusually careful employee has sole and complete charge and keeps it locked and inaccessible to others.

Situation in the Plant

Considerable attention should be given to the plant location of the oil house, or the part of the storehouse or power house which is to be set aside for conversion into an oil room. First thought should be to locate the oil room or house as close as possible to the railroad siding, dock or street in the realization that quite a considerable amount of time will always be lost in the laborious handling of heavy oil



Courtesy of S. F. Bowser & Co., Inc.

Fig. 10—Showing the interior of a modern oil house, with individual storage tanks arranged for ready accessibility. Note the means of hoisting oil drums automatically to the track above the tanks for emptying contents into permanent storage. It is obvious that every effort has been made to maintain cleanliness.

containers. Furthermore, considerable possibility of damage will be present both to lubricants and containers if the latter are rolled or tumbled about unnecessarily.

Where storage is properly located, however, containers will not be subject to any more handling than absolutely necessary in their transference from cars, boat or motor truck.

Handling of filled containers from one level to another requires hoisting. This must also be considered. In the first place, hoisting, whether by hand or by elevator, is expensive, but more to the point, it entails a certain amount of severe handling of the containers which may easily lead to contamination of the oils or greases through sprung seams, etc. Wood barrels especially will suffer, and warped and cracked heads, or the jarring loose of particles of the glue lining will often occur. For this reason, it can be appreciated that any damage to the container which may break the seal and lead to contamination of the contents through entry of water or foreign substances is a serious matter.

Advantage of One Level

To prevent this as far as possible "one level" handling is always best. In other words, where practicable the platform of the oil house or

storage room should be on a level with the car floors or dock, or, where containers are to be delivered by motor truck, on a level with the floor of the average truck. Under such conditions, containers can be rolled, trundled on hand trucks, or handled by a portable conveyor, directly from the delivering medium to the filling hatch of the storage tanks, where this is located at the floor level, or to the hoisting device above the tanks if they extend above the floor. A minimum of labor, time lost, damage to containers and waste or contamination of the lubricants will be the result of such a layout.

Courtesy of S. F. Bowser & Co., Inc.

Fig. 11—In contrast with the oil storage facilities shown in Fig. 10, note the above arrangement. Products are stored in shipping containers and general conditions are such as to fail to insure complete protection of lubricants.

Constructional Details

Whatever the method of storage, the general construction should be fireproof throughout, with brick, tile or concrete walls and floor. The roof should be tile, metal or slate on steel beams or rafters. The danger of fire in a modern oil storage house will usually be negligible; yet constructional features of fireproof nature are the best sort of insurance, and first cost, unless prohibitive, should not be spared.

In addition, cleanliness will be far easier maintained with such construction than where woodwork is used, for this would soon become splashed and oil-soaked.

Doors and windows also require consideration. Best practice recommends as few of these as possible, and those that are used should be of steel-frame or roller type, fitted with wire glass and automatic closing devices. A final precaution is the installation of suitable fire extinguishing equipment.

Storage Tank Details

With an understanding of the features which a modern oil house or storage room should embody, the question of storage tanks and their appurtenances require consideration. In any plant the type, size or number of storage tanks that it may be necessary to install will depend upon the volume and nature of the lubricants that are to be stored. In general, where an oil house is involved, it will usually be practicable to build it with a basement, and provide for bulk storage tanks located therein; the main floor in such a house would thus serve as the receiving and delivering room, the tops of the tanks projecting above the floor or not, according to their design. Many lubricating engineers prefer to keep all tankage below the floor level, devoting this entire area to delivery pumps and other necessary accessories.

The number of such tanks required will in general depend upon the number of different grades of lubricants necessary for plant operations. In every case, the rate of plant consumption should be considered. Where, for example, but small quantities of certain products are to be stored for any length of time it will be best to keep them in the shipping containers over the period of storage in the interest of economy of space and expense, rather than plan for transference to permanent tanks. In the case of semi-solid lubricants, such as gear lubricants, transfer will necessitate some form of heating system to bring about temporary liquefaction. As a result, unless such products are received in lots of several barrels, as in steel mill or railroad service, it will be best to store them in the shipping drums.

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